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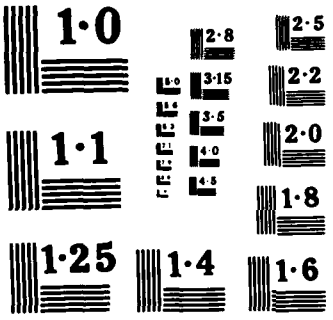

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LONGITUDINAL STUDY OF HEALTH RISKS ASSOCIATED WITH U.S. NAVY DIVER CLASSIFICATIONS

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LONGITUDINAL STUDY OF HEALTH RISKS ASSOCIATED WITH U.S. NAVY DIVER CLASSIFICATIONS

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SUMMARY

Problem

U.S. Navy diving, which consists of several diver classifications, encompasses a wide spectrum of hazardous duties, from work at depths in a saturated state for extended periods of time to underwater search for explosives. While diving in general entails risks of injury and illness, little is known of the health effects that may be associated with each specific diver classification. To protect the safety and health of Navy divers, these potential health risks need to be identified.

Objectives

The objectives of this longitudinal study were to identify the health risks (hospitalizations) unique to eight diver classifications and to determine if the observed age-adjusted frequencies of hospitalizations were significantly higher than expected for all divers. Included in this study were divers considered to be experienced in one of the following classifications: second class, explosive ordnance disposal (EOD), underwater demolition team/combatant swimmer (UDT/SEAL), first class, saturation, master, diving officer, and helium-oxygen (HeO_2) diving officer.

Approach

Participants included 3,748 U.S. Navy male divers who had at least 10 dives in one of eight diver classifications and who also had 50% or more of their dives and bottom hours in that specific classification. These diving data were provided by the Naval Safety Center in Norfolk which is the repository for all of the Diving Log-Accident/Injury Reports (OPNAV 9940/1) that date back to January 1968. Birth year and information on dates and reasons for separation from service were obtained from the *Officer and Enlisted Career History* files. Records from the Medical Inpatient file were extracted for divers who were hospitalized during the period January 1968 through December 1979.

Frequencies were tabulated of hospitalizations that occurred after the diver's beginning date in his primary class. These frequencies were condensed into 16 major diagnostic categories, and hospitalization rates per 10,000 strength were computed within each diver classification. Comparisons of rates across the eight classifications identified diagnostic categories with the highest rates. Miettinen probabilities were calculated to determine whether observed age-adjusted frequencies of hospitalizations for each classification were significantly higher than expected for all enlisted divers or diving officers.

Results

The diagnostic categories with the highest hospitalization rates included accidental injuries, musculoskeletal disorders, and diseases of the digestive system. Total hospitalization rates varied from a low of 231.9 per 10,000 for diving officers to a high of 1,301.0 for master divers. These rates were not age adjusted which explained in part the higher rate among master divers, the oldest group in this study. Five of the eight diver classifications (EOD, UDT/SEAL, second class, first class, and diving officers) had significantly fewer hospitalizations than expected for total admissions and for several diagnostic categories. Other results showed that master divers had higher than expected age-adjusted hospitalization frequencies for accidental injuries (none of

which were diving related), respiratory disorders, and symptoms and ill-defined conditions. Significantly higher than expected frequencies were observed for musculoskeletal disorders among UDT/SEAL divers.

Conclusions

The lower observed than expected frequencies of hospitalizations for five of the eight groups indicated that Navy divers generally are in excellent health. Explanations for these results included physical fitness, diver requalifications, elitism and camaraderie, love of diving, monetary remuneration, and symptom denial. No group had a higher than expected frequency for total hospitalizations. The elevated hospitalization rate for musculoskeletal disorders among UDT/SEAL divers may be attributable to the enormous physical demands placed on these divers. The significantly higher observed than expected frequency of hospitalization for symptomatology among master divers seemed to be a reflection of the hazardous dives these men performed throughout their diving careers. These results suggested that the type of dive performed probably had a greater influence on health outcomes than the extent of diving exposure.

Recommendations

Divers should be apprised of the potential diving-related health risks of musculoskeletal disorders and pain symptomatology, which might encourage divers to seek medical treatment at the outset of such conditions and to report the diving hazards that may be causative factors. At present, preventive measures focus on continued adherence to the techniques developed to protect the safety and excellent health status of U.S. Navy divers.

Longitudinal Study of Health Risks Associated with U.S. Navy Diver Classifications

U.S. Navy diving, which consists of several diver classifications, encompasses a wide spectrum of hazardous duties, including underwater search for explosives; work at depths in a saturated condition for extended periods of time; performance of salvage, unconventional, and special warfare operations; and beach reconnaissance and underwater surveillance. While performing these duties, divers are aware of the risks of injury although the probability that any dive will result in a mishap has been reported to be quite low or 0.17% (1). Injuries range in severity from the less serious barotitis media to the very serious conditions of decompression sickness, air embolism, and pulmonary barotrauma (2-4).

In addition to injuries, divers are apprised of the potential adverse health consequences of diving. Several studies conducted during the past decade have identified only a few long-term health effects attributable to diving, one of which is the rarely occurring disorder of dysbaric osteonecrosis (5). Other results determined that, although the numbers of hospitalizations were low, divers with decompression sickness were at increased risk of subsequently being hospitalized for various symptoms and headache; diseases of the pancreas, intestines, and gallbladder; and diseases of the arteries and veins (6). Enlisted divers had higher hospitalization rates compared with those in a control sample for environmentally induced disorders and deflected nasal septum as well as joint disorders at ages 23-28 (7). Diving officers were at risk for joint disorders and diseases of the nervous system whereas controls had higher hospitalization rates for stress-related disorders (8).

While results of those studies provided information on the health risks of diving officers and enlisted personnel, little is known of the health effects that may be associated with specific classifications of divers. Previous research on diver classifications centered primarily on prediction of success in diver, second class, or underwater demolition team training (9-14) or prediction of performance during diving (15-16).

Each diver classification requires the individual so assigned to complete a specific training program before being qualified to perform those types of dives. At the entry level is the second class diver who learns to use SCUBA and the MK-1 bandmask and the MK-12. Second class divers do not dive beyond 190 feet. According to Berghage et al. (17), these individuals dive more than any other classification, accounting for 25% of all dives. After serving at least one year as a second class diver, eligible applicants can apply for first class diver training in which divers are taught underwater welding, use of underwater explosives, recompression chamber operation, and supervisory techniques. First class divers are qualified to dive with mixed-gas systems to 300 feet. The pinnacle of achievement in Navy diving is master diver which can only be pursued by first class or saturation divers after two years at those diving skill levels. Saturation divers must complete a 14-week course which qualifies them to perform diving tasks to 850 feet. The master diver program is a rigorous 5-week training program, and graduates are recognized as the most proficient in their field.

In addition to these four classifications, there are several special diver series, including explosive ordnance disposal diver (EOD) and underwater demolition team diver/combatant swimmer (UDT/SEAL). EOD divers detect, render safe, evaluate, and dispose of explosive ordnance, nuclear

weapons, and chemical and biological agents. They also perform salvage operations to recover materials located underwater as well as conduct day and night underwater searches for ordnance. UDT/SEAL divers are trained to use all types of SCUBA and to collect hydrographic, terrain, and target intelligence. These divers perform unconventional and special warfare operations.

Navy diving also includes several classifications of officers. For the purpose of this study, only the records for the two categories of diving officer and helium-oxygen (HeO_2) diving officer will be examined. The classification of diving officer is a general one whereas the HeO_2 diving officer must complete a 23-week course consisting of 16 weeks of training as a salvage officer followed by seven weeks of training in usage of helium-oxygen mixtures.

The specific objectives of this longitudinal study were to identify the health risks (hospitalizations) unique to eight diver classifications and to determine if the observed frequencies of hospitalizations were significantly higher than expected for all divers. Only divers considered to be experienced in one of these classifications were included in this study.

METHOD

Participants

Participants included 3,748 U.S. Navy male divers whose primary diver classification was one of the following: second class, EOD, UDT/SEAL, first class, saturation, master, diving officer, and HeO_2 diving officer. Diver classification information was obtained from the computerized file of Diving Log-Accident/Injury Reports (OPNAV 9940/1), which was provided to the Naval Health Research Center, San Diego, by the Naval Safety Center in Norfolk, VA. Selection of experienced divers for each classification was accomplished by extracting records of divers who had at least 10 dives in one of the eight classifications and who also had 50% or more of their dives and bottom hours in that specific classification.

Other data extracted from the diving log file included information pertinent to both the diver's primary diver classification and his career totals to date: number of dives, bottom hours, and diving months. Birth year and information on dates and reasons for separation from service were obtained from the Officer and Enlisted Career History files. Table 1 is a presentation of descriptive data on each of the eight diver classifications. The oldest divers, on the average, were in the master diver and HeO_2 diving officer classifications whereas the youngest were second class divers. Divers with the highest mean number of dives in both their primary classification and overall career total for the 1968 to 1979 time period were first class, second class, and EOD. Saturation and first class divers had the highest mean number of bottom hours. Diving officers and HeO_2 diving officers had the least diving experience as reflected by their lower means for number of dives and bottom hours. The total mean number of months in the diver's primary classification ranged from 29.1 months for second class divers to 70.5 for EOD divers.

Procedure

Records from the Medical Inpatient file were extracted for divers who were hospitalized in a naval medical facility during the period January 1968 through December 1979. Specific data selected from this file, which was provided to the Naval Health Research Center by the Naval Medical Data Services Center, Bethesda, Maryland, included dates and diagnoses for all hospitalizations as well as the diver's age at admission and the cause code for each accidental injury

TABLE 1

DIVER CHARACTERISTICS BY CLASSIFICATION, 1968-1979

	Diver Classification							
Characteristic	Second Class	EOD	UDT/SEAL	First Class	Saturation	Master Diver	Diving Officer	HeO_2 Diving Officer
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Birth year	1952	1944	1948	1944	1943	1934	1946	1940
No. of dives in class	87.1	89.0	45.5	124.7	47.0	52.9	36.0	30.9
Total no. of dives	106.8	104.2	55.1	156.4	66.8	62.3	49.0	41.9
No. of bottom hours in class	80.3	56.7	49.4	115.1	144.6	39.9	30.0	25.9
Total no. of bottom hours	90.6	64.8	54.4	136.1	167.3	45.3	37.2	33.3
No. of months in class	29.1	70.5	59.4	64.9	58.3	53.3	45.7	52.4
Total no. of months diving	37.9	80.5	64.0	79.7	80.1	64.9	53.3	61.0
No. of divers	1,344	495	746	762	108	69	140	84

NOTE: Diving records compiled prior to 1968 would not be included in these mean values; therefore, the means would be underestimates for the older groups.

hospitalization. Numeric codes for each diagnosis were adapted from the Eighth Revision of the International Classification of Diseases Adapted for Use in the United States (ICDA-8). Frequency distributions of hospitalizations for each diagnosis were computed in each diver classification by age interval (17-22, 23-28, 29-34, 35-40, and 41 years of age and older). These frequencies were condensed into 16 ICDA-8 diagnostic categories. Because this longitudinal study was designed to identify illnesses and injuries attributable to specific diver classifications, only those hospitalizations that occurred after the diver began diving in that class were included in these tabulations.

To identify the illnesses and injuries accounting for the largest proportions of hospital admissions, hospitalization rates per 10,000 strength were computed within each classification by diagnostic category, using frequencies of hospitalizations and person-years. Person-years were computed by summing the number of men on active duty for each year beginning with the first diving year in class through 1979. For example, all divers who began diving in a specific class in 1974 and stopped diving in early 1979 would contribute five person-years each to the total for that class. The frequencies of hospitalizations were divided by person-years and multiplied by 10,000 to obtain the annual hospitalization rate for each category.

To identify the health risks unique to each classification, the frequencies of hospitalizations were age adjusted to eliminate the effects of age (18), and comparisons then were conducted between age-adjusted observed and expected frequencies of hospitalizations by disease categories. The numbers of expected hospitalizations were based on the distribution of disease in the total enlisted diver or diving officer populations. Miettinen probabilities were calculated to determine the significance of differences between observed and expected frequencies (19).

RESULTS

Hospitalization rates by diver classification

Across diver classifications, total hospitalization rates varied from a low of 231.9 per 10,000 for diving officers to a high of 1,301.0 for master divers (see Table 2). The major diagnostic categories were rank ordered across all diver classifications according to frequency of hospitalizations. The highest rate for six of the eight groups was for accidental injuries; diving officers had the lowest rate with no hospitalizations whereas master divers had the highest with 408.2. The proportion of all hospitalizations caused by accidental injuries was 28.7%, and less than 6.2% of these hospitalizations were attributed to a diving or swimming mishap.

The second-ranked category was musculoskeletal disorders which accounted for 14.6% of all admissions. Rates per 10,000 ranged from 21.1 for HeO_2 diving officers to 159.6 for UDT/SEAL divers. Diseases of the digestive system represented 11.1% of the total. The three top-ranked categories accounted for more than one-half (54.4%) of all hospitalizations. Other high rates were noted for mental disorders with the highest observed among saturation and first class divers and no admissions recorded for the two diving officer groups. All of the hospitalizations for mental disorders among saturation divers and 64.3% of those for first class divers were for alcohol-related problems.

Perhaps the most notable results were the low hospitalization rates among diving officers and HeO_2 diving officers. Also distinctive were the relatively low rates for the majority of diagnostic categories among EOD and second class divers.

Age-adjusted hospitalizations by diver classification

Age-adjusted expected and observed frequencies of hospitalizations by diagnostic category are presented by diver classification in Table 3. Comparisons within each diver group determined whether the observed frequencies were significantly higher or lower than expected for all diving officers or all enlisted divers. Five of the eight diver classifications (EOD, UDT/SEAL, second class, first class, and diving officers) had significantly fewer hospitalizations than expected for total admissions and for several diagnostic categories.

Significantly higher than expected frequencies of hospitalizations were observed in the diver classifications of UDT/SEAL and first class for musculoskeletal disorders and infective and parasitic diseases, respectively. More than 50% of the musculoskeletal disorders in hospitalized UDT/SEAL divers were for diseases of the joint while hepatitis and other viral diseases accounted for one-half of the infective and parasitic disease hospitalizations for first class divers. Master divers had higher than expected hospitalization frequencies for accidental injuries (none of which were diving related), respiratory diseases, and symptoms and ill-defined conditions. For the latter two categories, the specific diagnoses with the highest frequencies included other diseases of the upper respiratory tract and respiratory system and symptoms referable to the limbs and joints and to the respiratory and nervous systems. Saturation divers had higher than expected hospitalizations for diseases of the digestive system, with hernias accounting for 38.5% of the total.

TABLE 2

ANNUAL HOSPITALIZATION RATES PER 10,000 BY DIAGNOSTIC CATEGORY AND DIVER CLASSIFICATION, 1968-1979

	Diver Classification							
	Second Class	EOD	UDT/SEAL	First Class	Saturation	Master Diver	Diving Officer	HeO_2 Diving Officer
Accidents, poisonings, and violence	239.0	153.4	309.8	213.2	161.5	408.2	0	126.8
Diseases of the musculoskeletal system	101.8	84.9	159.6	120.9	88.1	153.1	72.5	21.1
Diseases of the digestive system	66.5	49.0	84.5	118.9	190.9	102.0	87.0	63.4
Mental disorders	47.8	68.5	39.9	86.1	88.1	25.5	0	0
Diseases of the respiratory system	45.7	26.1	35.2	63.5	44.0	204.1	29.0	63.4
Symptoms and ill-defined conditions	39.5	19.6	28.2	45.1	44.0	153.1	0	21.1
Diseases of the circulatory system	24.9	32.6	39.9	43.0	88.1	51.0	0	0
Diseases of the genitourinary system	47.8	39.2	28.2	22.6	58.7	0	14.5	21.1
Infective and parasitic diseases	12.5	35.9	28.2	63.5	14.7	51.0	0	0
Diseases of the nervous system and sense organs	31.2	16.3	37.6	26.6	29.4	76.5	0	63.4
Diseases of the skin and subcutaneous tissue	24.9	22.8	28.2	32.8	0	25.5	14.5	0
Neoplasms	12.5	13.0	30.5	28.7	29.4	0	0	0
Supplementary classifications--special conditions	18.7	19.6	14.1	20.5	44.0	51.0	0	0
Congenital anomalies	12.5	13.0	16.4	14.4	0	0	14.5	0
Endocrine, nutritional, and metabolic diseases	2.1	13.0	2.4	4.1	14.7	0	0	21.1
Diseases of blood and blood-forming organs	2.1	0	0	4.1	0	0	0	0
Total hospitalization rate	729.4	607.0	882.4	908.0	895.7	1,301.0	231.9	401.7
Person-years at risk	4,812	3,064	4,261	4,879	681	392	690	473

TABLE 3

AGE-ADJUSTED EXPECTED AND OBSERVED HOSPITALIZATION FREQUENCIES BY DIAGNOSTIC CATEGORY AND DIVER CLASSIFICATION, 1968-1979

	Second Class		EOD		UDT/SEAL		First Class Saturation Master Diver						Diving Officer		HeO_2 Diving Officer	
Diagnostic Category	Ex.	Ob.	Ex.	Ob.	Ex.	Ob.	Ex.	Ob.	Ex.	Ob.	Ex.	Ob.	Ex.	Ob.	Ex.	Ob.
Accidents, poisonings, and violence	140	115*	79	47**	122	132	126	104*	17	11	8	16**	6	0**	5	6
Diseases of the musculo-skeletal system	48	49	43	26**	49	68**	68	59	10	6	7	6	5	5	3	1
Diseases of the digestive system	43	32*	31	15**	39	36	49	58	7	13*	5	4	4	6	4	3
Mental disorders	27	23	22	21	26	17*	36	42	5	6	3	1	2	0	2	0
Diseases of the respiratory system	57	22**	23	8**	43	15**	36	31	4	3	2	8**	2	2	1	3*
Symptoms and ill-defined conditions	23	19	14	6**	20	12*	22	22	3	3	2	6*	2	0	1	1
Diseases of the circulatory system	14	12	15	10	16	17	23	21	3	6	4	2	2	0	2	0
Diseases of the genitorurinary system	26	23	16	12	23	12**	25	11**	3	4	2	0	1	1	1	1
Infective and parasitic diseases	35	6**	13	11	26	12**	20	31*	2	1	1	2	2	0	1	0
Diseases of the nervous system and sense organs	14	15	11	5*	13	16	18	13	3	2	2	3	2	0	2	3
Diseases of the skin and subcutaneous tissue	30	12**	13	7*	24	12**	21	16	3	0*	2	1	1	1	0	0
Neoplasms	9	6	8	4	9	13	13	14	2	2	1	0	1	0	1	0
Supplementary classifications--special conditions	14	9	9	6	12	6*	15	10	2	3	1	2	0	0	0	0
Congenital anomalies	5	6	4	4	5	7	7	7	1	0	1	0	0	1	0	0
Endocrine, nutritional, and metabolic diseases	3	1	2	4	3	1	4	2	0	1	1	0	0	0	0	1
Diseases of blood and blood-forming organs	2	1	1	0	1	0	1	2	0	0	0	0	0	0	0	0
Total hospitalization rate	489	351**	305	186**	431	376**	483	443*	67	61	41	51	30	16**	25	19

NOTE: The column headings for expected and observed frequencies are abbreviated to Ex. and Ob. *$p < 0.05$. **$p < 0.01$.

DISCUSSION

Results of this study indicated that five of the eight diver groups had significantly fewer total hospitalizations than expected while no group had more observed than expected admissions. Such findings suggested that experienced U.S. Navy divers generally are in excellent health. Four of the eight diver groups (master, UDT/SEAL, first class, and saturation) differed from others in that the number of hospitalizations was significantly higher than expected for six diagnostic categories. An examination of the frequencies of specific diagnoses within four of the six categories showed that the diagnoses comprising the significantly higher hospitalization rates probably were unrelated to diving: hernias, hepatitis and other viral diseases, accidental injuries (all of which had a nondiving-related cause code), and diseases of the upper respiratory tract. The other diagnoses, musculoskeletal disorders and symptoms (referable to the limbs and joints and to the respiratory and nervous systems), were more likely to be diving related. The diver groups identified in this study to be at risk for these conditions were UDT/SEAL and master divers, respectively.

The elevated hospitalization rate for musculoskeletal disorders among UDT/SEAL divers may be attributable to the enormous physical demands placed on these divers. Not only is the initial UDT/SEAL training arduous and highly stressful, but severe physical stressors are involved in performing the posttraining diving duties and participating in the rigorous physical fitness regimens. EOD divers, on the other hand, have significantly fewer hospitalizations than expected for musculoskeletal disorders. These divers typically engage in diving tasks that require less strength, physical exertion, and stamina than those of UDT/SEAL divers. Another noteworthy finding is that EOD divers are among the most experienced divers in this study, which is evidenced by their relatively high means for number of dives and diving months. The type of dives performed, therefore, seems to have more of an influence on health outcomes than extent of diving exposure.

Master divers have a significantly higher than expected age-adjusted frequency of hospitalizations for symptoms and ill-defined conditions. Because these divers are considered to be the most proficient in the field, they would be expected to have histories of being assigned to more hazardous dives than less experienced divers. The high risk or dangerous nature of these dives probably increases the likelihood of a subsequent hospitalization for pain symptomatology.

These diving-related health risks of musculoskeletal disorders and symptoms and ill-defined conditions correspond with results of other research. Curley et al. (15), for example, reported that all six divers in a simulated saturation dive complained of pain throughout all phases of the dive, but especially during compression and decompression. Research cited by Dickey (4) indicated that joint pain, the most common form of decompression sickness, comprised from 60 to 79% of all cases of decompression sickness. Results summarized at the outset concluded that divers were at increased risk of bone tissue deterioration and joint disorders; arthritis also was identified as a secondary condition of the rarely occurring dysbaric osteonecrosis (3). Moreover, the hospitalization rates for all but one of the enlisted groups in this study were higher for musculoskeletal disorders than the previously reported rate (87.4 per 10,000) for a Navy enlisted population (20).

Other results of the present investigation revealed several lower than expected frequencies of hospitalizations in divers. Factors that play a role in these lower frequencies include physical fitness, diver requalifications, elitism and camaraderie, love of diving, monetary remuneration, and symptom denial. Research cited above has shown that individuals who successfully complete various diver training programs typically are the embodiment of excellent physical and mental conditioning. Subsequent to graduation, divers must pass periodic qualification standards in order to remain on active diving status.

Also related to these lower than expected frequencies of hospitalizations are elitism and camaraderie. Navy enlisted divers are considered to be members of one of the Navy's elite occupational groups, particularly as they progress through the hierarchy from second class to master diver. Closely associated with elitism are camaraderie and esprit de corps which evolve from the necessity among divers to depend on each other during a dive and to assume responsibility for maintaining a high level of physical conditioning not only for their own well-being but also to protect the health of divers who work with them.

Two other important incentives for maintaining one's health and physical fitness are a love of diving and monetary remuneration. Simply stated, most divers love to dive and would rather engage in this occupation than any other. Navy personnel receive extra pay for diving which may serve as another reason, although probably one of lesser importance, for pursuing a military diving career.

The possibility that these lower rates reflect a certain degree of symptom denial also should be addressed. Diving involves numerous physical and psychological stresses. Because the image of the diver is one of strength and endurance, some divers may feel less inclined than others to report an injury or illness.

The implications of this study are that divers should be apprised of the potential diving-related health risks of musculoskeletal disorders and pain symptomatology. An increased awareness of these risks may encourage divers to seek medical treatment during the initial stages of such conditions. Divers also should report specific diving hazards that might be causative factors of these disorders; these dangerous conditions then could be corrected or avoided. At present, preventive measures focus on continued adherence to the techniques developed to protect the safety and excellent health status of U.S. Navy divers. Even under the best of diving conditions, however, a small segment of the diving population, particularly UDT/SEAL and master divers, will experience pain and/or a musculoskeletal disorder, as shown by this study.

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The objectives of this longitudinal study were to identify the health risks (hospitalizations) unique to eight U.S. Navy diver classifications (n = 3,748) and to determine if the observed age-adjusted frequencies of hospitalizations were significantly higher than expected for all divers. Results indicated that five of the eight diver groups had significantly fewer total hospitalizations than expected while no group had more observed than expected admissions. The only diving-related health risks identified were the higher

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rates for musculoskeletal disorders in UDT/SEAL divers and symptoms and ill-defined conditions in master divers. The type of dive performed seemed to have more of an influence on health outcomes than extent of diving exposure. The lower than expected frequencies of hospitalizations were explained in terms of physical fitness, diver requalifications, elitism and camaraderie, love of diving, monetary remuneration, and symptom denial.

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